(12) EUROPEAN PATENT APPLICATION

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(54) High precision sub-pixel spatial alignment of digital images

(57) A high precision sub-pixel spatial alignment of digital images, one from a reference video signal and another from a corresponding test video signal, uses an iterative process and incorporates spatial resampling along with basic correlation and estimation of fractional pixel shift. The corresponding images from the reference and test video signals are captured and a test block is overlaid on them at the same locations to include texture from the images. FFTs are performed within the test block in each image, and the FFTs are cross-correlated to develop a peak value representing a shift position between the images. A curve is fitted to the peak and neighboring values to find the nearest integer pixel shift position. The test block is shifted in the test image by the integer pixel shift position, and the FFT in the test image is repeated and correlated with the FFT from the reference image. The curve fitting is repeated to obtain a fractional pixel shift position value that is combined with the integer pixel shift value to update the test block position again in the test image. The steps are repeated until an end condition is achieved, at which point the value of the pixel shift position for the test block in the test image relative to the reference image is used to align the two images with high precision sub-pixel accuracy.
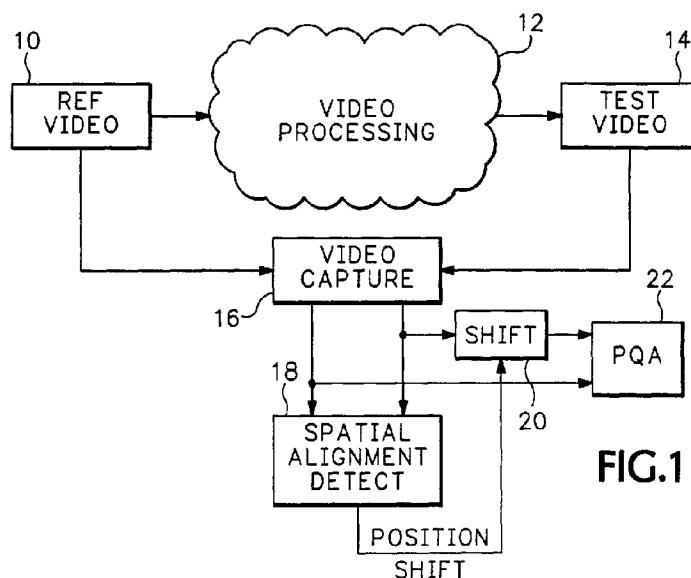
FIG.1

EP 0 999 521 A2

Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to the matching
of digital images, and more particularly to high precision
sub-pixel spatial alignment of digital images.

[0002] Accurate spatial alignment of digital images is
of fundamental importance to many applications. One
such application is the determination of picture quality
using an instrument, such as the PQA200 Picture Qual-
ity Analyzer manufactured by Tektronix, Inc. of Wilson-
ville, Oregon, USA, where images from a reference vid-
eo signal are compared with corresponding images from
a test video signal that is a processed version of the ref-
erence video signal. The better the spatial alignment be-
tween a reference image and a corresponding test im-
age, the more accurate the determination of the amount
of degradation of the test video signal due to the
processing.

[0003] At pages 480-484 of Computer Image
Processing and Recognition (1979) published by Aca-
demic Press, Ernest L. Hall describes a basic correlator
method for template matching, which may be used for
image alignment. Likewise J.J. Pearson et al in an article
entitled Video-Rate Image Correlation Processor (IOCC
1977) published in SPIE Vol. 119 *Application of Digital
Image Processing,* pages 197-205, describe a variant
of the basic correlator method that uses phase informa-
tion. For digital images with integer pixel shifts these cor-
relation methods may be very accurate. However for a
broader class of shifts, which involves both integer and
fractional pixel shifts, the precision of the sub-pixel
alignment becomes a very serious matter. Pearson et
al describe a method for estimating the sub-pixel shifts
by quadratic interpolation using the correlation values
in the neighborhood of a peak. However, since the quad-
ratic interpolation function does not necessarily match
the true image shifting function, the accuracy obtained
by the quadratic interpolation is limited.

[0004] What is desired is a high precision sub-pixel
spatial alignment of digital images.

BRIEF SUMMARY OF THE INVENTION

[0005] Accordingly the present invention provides for
high precision sub-pixel spatial alignment of digital im-
ages using an iteration method and spatial resampling.
A high precision sub-pixel spatial alignment of digital im-
ages, one form a reference video signal and another
from a corresponding test video signal, uses an iterative
process and incorporates spatial resampling along with
basic correlation and estimation of fractional pixel shift.
The corresponding images from the reference and test
video signals are captured and a test block is overlaid
on them at the same locations to include texture from
the images. FFTs are performed within the test block in
each image, and the FFTs are cross-correlated to de-

velop a peak value representing a shift position between
the images. A curve is fitted to the peak and neighboring
values to find the nearest integer pixel shift position. The
test block is shifted in the test image by the integer pixel
shift position, and the FFT in the test image is repeated
and correlated with the FFT from the reference image.
The curve fitting is repeated to obtain a fractional pixel
shift position value that is combined with the integer pix-
el shift value to update the test block position again in
the test image. The steps are repeated until an end con-
dition is achieved, at which point the value of the pixel
shift position for the test block in the test image relative
to the reference image is used to align the two images
with high precision sub-pixel accuracy.

[0006] The objects, advantages and other novel fea-
tures of the present invention are apparent from the fol-
lowing detailed description when read in conjunction
with the appended claims and attached drawing.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF
THE DRAWING

[0007] Fig. 1 is a block diagram view of a system for
high precision sub-pixel spatial alignment of digital im-
ages according to the present invention.

[0008] Fig. 2 is an illustrative view of a comparison of
an image from a reference video signal and an image
from a corresponding test video signal to be spatially
aligned with high precision sub-pixel accuracy accord-
ing to the present invention.

[0009] Fig. 3 is a flow diagram view of a high precision
sub-pixel spatial alignment algorithm according to the
present invention.

[0010] Fig. 4 is an illustrative view of a cross-correla-
tion surface showing a peak location for the high preci-
sion sub-pixel spatial alignment algorithm according to
the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0011] Referring now to Fig. 1 an original, reference
video signal from a source 10 is input to a video process-
ing network 12. The video processing network 12 may
include one or more compression/decompression pass-
es. The output from the video processing network 12 is
input to a decoder or similar device 14 to provide a
source of a test video signal. The reference and test vid-
eo signals are input to a video capture module 16 that
captures corresponding images or frames from the two
video signals. The corresponding image pairs from the
video capture module 16 are input to a high precision
sub-pixel spatial alignment detect module 18 to deter-
mine a position shift between the images of the refer-
ence video signal and the images of the test video sig-
nal. The position shift from the spatial alignment detect
module 18 is input to a position shift module 20, which
may be either in the reference or test signal path, to pre-
cisely align the image pairs with sub-pixel accuracy from

the video capture module **16** for further processing, such as by a picture quality analyzer **22**.

[0012] In Fig. 2 the reference and test images **24**, **26** are shown having some texture **25**, i.e., not a matte image. As shown in the test image after processing the texture **25** has been shifted horizontally and/or vertically. An arbitrary test region or block **28** is formed, shown in this example as a rectangle, having a reference point Xo, Yo and is overlaid on both the reference and test images. For a rectangle as shown the reference point and horizontal and vertical extents ΔX, ΔY define the test region or block **28**. The test region **28** is located where there is substantial texture **25** in the images.

[0013] A high precision sub-pixel spatial alignment algorithm is shown in Fig. 3. An initialization module **30** provides the corresponding reference and test images together with a test block to a correlation measurement module **32**. The first step **34** in the initialization module 30 controls the video capture module **16** to capture corresponding reference and test images or frames from the reference and test video signals. The second step **36** establishes a test block for overlaying on the respective images in an area that has significant texture **25**. The first step **38** of the correlation measurement module **32** applies a fast Fourier transform (FFT) to the pixels of the images that lie within the test region. A cross-correlation step **40** is then performed in the FFT domain.

$$FFT(corr) = FFT(ref)^*FFT(tst)$$

$FFT^{-1}(corr)$ produces correlation coefficients for every shift point within the test region, which may be represented in the form of a surface **42** as shown in Fig. 4. The position of a peak **44** in the surface **42** indicates the amount of shift in position between the reference and test images. A curve-fit step **46** provides a nearest integer pixel shift position for the peak **44** based upon the coefficients for the peak position and the positions up, down, left and right from the peak position. The pixel shift position from the correlation measure module **32** is input to an update shift position step **48**. For the first iteration only the nearest integer pixel shift position is used.

[0014] A testing step **50** checks the amount of position shift determined from the update shift position step **48** and the number of iterations against specified parameters to determine whether the spatial alignment algorithm is done. If the number of iterations is equal to the specified number, or the amount of update is less than a specified noise value, then the shift position value from the update step **48** is provided as an output pixel shift position and the algorithm ends. Otherwise a shift test block step **52** shifts the test region in the test image by the value from the update position step **48** so that the reference point is shifted to be X+X$_\Delta$, Y+Y$_\Delta$, where X$_\Delta$ and Y$_\Delta$ are the integer pixel shift position values. With the new position of the test region or block, the correla-

tion module **32** is applied again to obtain a fractional pixel shift value in X and Y. In the FFT step **38** only the test image is processed after the initial iteration. The FFT for the reference image does not change. The fractional pixel shift value is used to update the shift position in the update step **48** so that the shift position becomes Xo+X$_\Delta$+X$_f$, Yo+Y$_\Delta$+Y$_f$. It has been found that for most practical applications two fractional pixel shift position iterations produce satisfactory results. The final shift position value output from the spatial alignment detect module **18** is then used to spatially align the test and reference images as indicated above.

[0015] Thus the present invention provides high precision sub-pixel spatial alignment of digital images by using an iterative process to cross-correlate FFTs for a test block from each image in order to find a peak representative of a shift position between the images, then by fitting a curve to the correlation coefficients to determine a nearest integer pixel shift position, updating the position of the test block in the test image and repeating until a specified number of iterations occurs or a change in fractional pixel shift position is less than a noise value.

Claims

1. A method of high precision sub-pixel spatial alignment of digital images comprising the steps of:

   capturing a reference image from a reference video signal as one of the digital images and a corresponding test image from a test video signal as another of the digital images, where the test video signal represents the reference video signal after processing;

   overlaying an arbitrary test block on the reference and test images at corresponding locations that include texture;

   performing a fast Fourier transform for the portions of each image that lie within the test block to produce a reference FFT and a test FFT;

   cross-correlating the reference and test FFTs to produce a correlation surface having a peak correlation value, the position of the peak correlation value on the correlation surface being representative of a shift position between the reference and test images;

   fitting a curve to the peak and neighboring correlation values to determine an integer pixel shift position;

   updating the position of the test block overlaying the test image by the integer pixel shift position; and

   repeating the performing step for the test image, the correlating step for finding fractional pixel shift positions, and the updating step by adding the fractional pixel shift positions to the integer pixel shift position until an end condition

is achieved, the final position of the test block in the test image from the updating step relative to the initial position of the test block in the test image providing the high precision sub-pixel *5* shift alignment between the reference and test images.

2. A method of high precision sub-pixel spatial align- ment of digital images comprising the steps of:

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    cross-correlating in the frequency domain a test block for each of the digital images to produce a correlation surface having a peak correlation value at a particular position within the test *15* block;
    updating the test block in one of the digital im- ages as a function of the particular position; and repeating the cross-correlating and updating steps until a specified end condition is achieved, the final position of the test block in *20* the one of the digital images relative to the other digital image representing the high precision sub-pixel spatial alignment between the digital images.
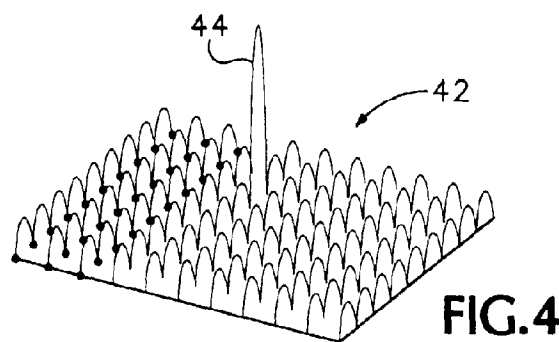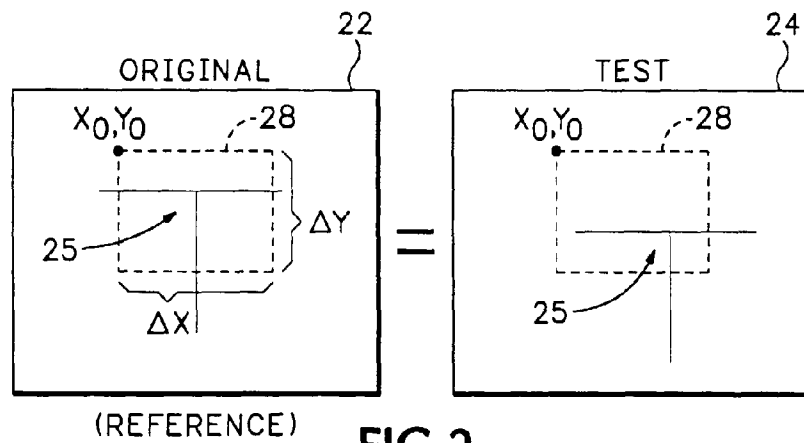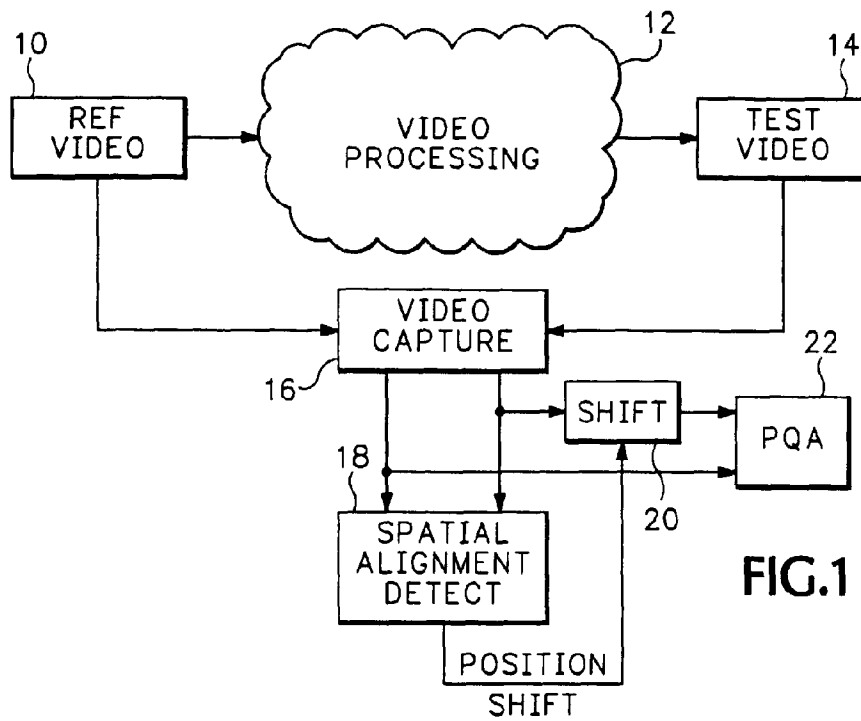
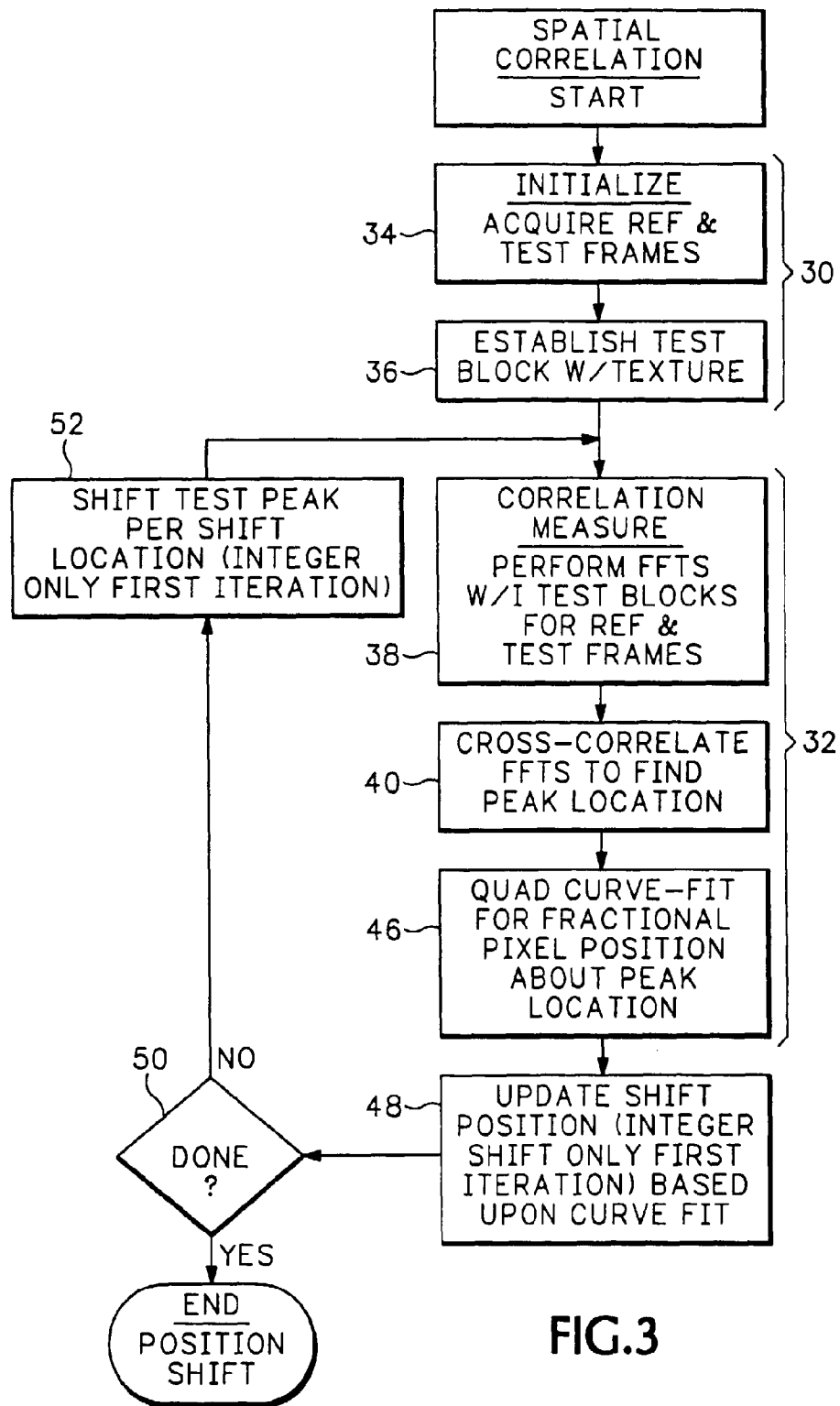   *25*

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FIG.1

FIG.2

FIG.4

FIG.3